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Radiation Transmission Measurements for a Lightweight Fabric

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INTRODUCTION

Radiation Shield Technologies has developed a lightweight fabric, shown in Fig. 1, with radiation shielding properties for X ray, gamma ray and beta particle emissions in the range of energies relevant to clinical and Homeland Security applications.

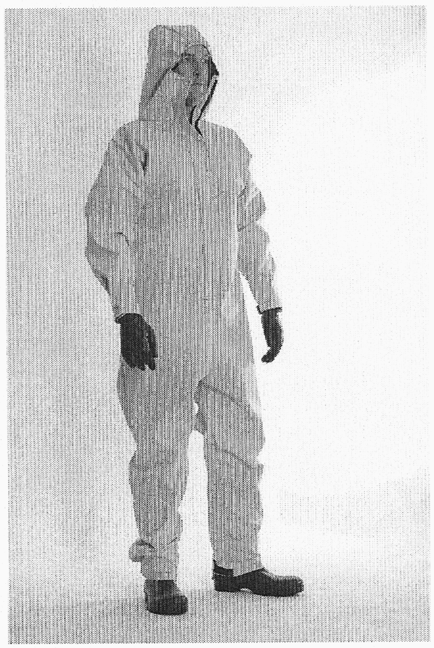

Fig. 1. Lightweight radiation protection suit made with Demron fabric

Detailed measurements were done to measure the shielding properties of this material against the spectra of standard radionuclides and x-ray generators. The mass attenuation coefficients were calculated using LLNL cross section data, a 3-D photon transport code, elemental weight fractions and the measured density of the fabric.

DESCRIPTION OF THE ACTUAL WORK

The radionuclides used were ^{241}Am, ^{109}Cd, ^{137}Cs, ^{60}Co (gamma rays) and ^{90}Sr/^{90}Y (beta particle emission). The detector used for the ^{241}Am and ^{109}Cd sources was a Victoreen 471RF ion chamber, which has a flat energy response over the energy range of interest, and TLDs 700 (LiF) for the ^{137}Cs and ^{60}Co sources. Standard materials such as tantalum, lead, copper and aluminum were compared to the fabric.

The transmission of x-ray intensity generated by 50 kV, 75 kV and 100 kV potentials, tube with reflected tungsten target, filtered through a 4-mm -thick aluminum plate, was studied with currents in the 10 mA range and exposure times for the TLDs of tens of minutes. The density and thickness were measured to be 3.14 g/cm^3 and 0.015 inch (0.38 mm) for a surface density of 0.12 g/cm^2. Elemental weight fractions were used in the model calculations. The fabric has a rubbery appearance and a cool feeling, a result of its high thermal conductivity. It is easy to handle and presents no toxic or disposal problems. Its flexibility permits it to be molded into any configuration or installed on irregular surfaces.

RESULTS

The mass attenuation coefficients for the fabric and tantalum were calculated using the TART radiation transport code. The code predictions are shown in Fig. 2 along with the mass attenuation coefficients based on our dose measurements.

A single layer of fabric attenuates 10-20 keV gamma rays by a factor of about 30. For ^{241}Am, the mass attenuation coefficient of 28 cm^2/g was measured for the 20 keV range and dropped to 2.3 cm^2/g for the 59 keV line. For 88 keV line of ^{109}Cd, the mass attenuation coefficient is 3.4 cm2/g corresponding to an order of magnitude increase in fabric attenuation for every 6 layers of fabric, once the low energy gamma rays have been removed. For 660 keV line of ^{137}Cs, the fabric mass attenuation coefficient is 0.08 cm^2/g corresponding to a fabric thickness of about 2.7 cm (or 72 layers) for a factor of two attenuation. For a factor of 10 attenuation, 29 g/cm^2 of fabric or 240 layers are required. For the 1.17 MeV and 1.33 MeV lines of ^{60}Co, the fabric mass attenuation coefficient is 0.05 cm^2/g, which is comparable to tantalum. For a factor of two attenuation, the fabric thickness required is 4.4 cm or 115 layers, while for an order of magnitude attenuation, 383 layers are required.

For the x-ray measurements at 50 kV, 75 and 100 kV potentials, the mass attenuation coefficients are 10.5 cm^2/g, 4.1 cm^2/g and 3.8 cm^2/g, respectively.

The model shows the close comparison between the Demron fabric and tantalum, a relationship that is borne out by the experimental data out to the megavoltage range. Even the location of the K and L edges in the range below 100 keV matches closely due to the detailed characteristics of the fabric

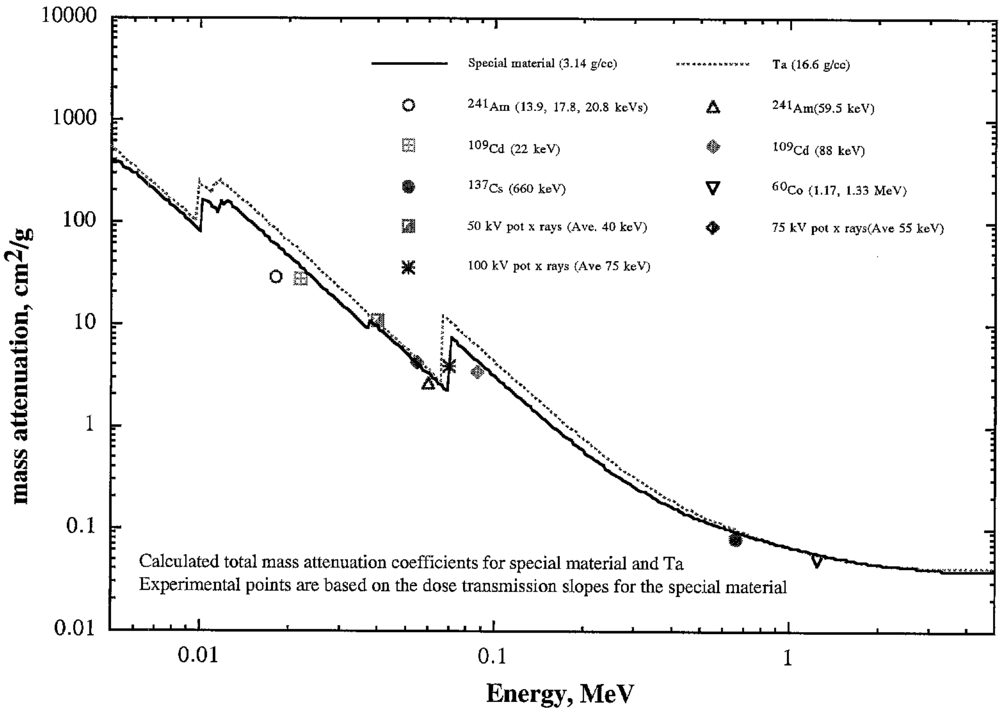

Fig. 2. Experimental results compared with TART model calculations